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Maternal communicative behaviours and interaction quality as predictors of language development: findings from a community-based study of slow-to-talk toddlers.

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Maternal communicative behaviours and interaction quality as predictors of language development: Findings from a community-based study of slow-to-talk children

Running head: Communicative behaviours and interaction quality

Keywords: Mother-child interaction, Language development, Parenting, Longitudinal Study

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Abstract

Background. Identifying risk and protective factors for language development informs interventions for children with developmental language disorder (DLD). Maternal responsive and intrusive communicative behaviours are associated with language development. Mother-child interaction quality may influence how children use these behaviours in language-learning.

Aims. We aimed to identify (1) communicative behaviours and interaction quality associated with language outcomes, (2) whether the association between a maternal intrusive behaviour (directive) and child language scores changed alongside a maternal responsive behaviour (expansion), and (3) whether interaction quality modified these associations.

Methods & Procedures. Language skills were assessed at 24-, 36-, and 48-months in 197 community-recruited children who were slow-to-talk at 18-months. Mothers and 24-month-olds were video-recorded playing at home. Maternal praise, missed-opportunities, and successful and unsuccessful directives (i.e. whether followed by child) were coded during a ten-minute segment. Interaction quality was rated using a seven-point Fluency and Connectedness (FC) scale, during a five-minute segment. Linear regressions examined associations between these behaviours/rating and language scores. Interaction analysis and simple slopes explored effect modification by FC.

Outcomes & Results. There was no evidence that missed-opportunities or praise were associated with language scores. Higher rates of successful directives in the unadjusted model, and unsuccessful directives in the adjusted model were associated with lower 24-month-old receptive language scores (e.g. unsuccessful directives effect size (ES) = -0.41). The association between unsuccessful directives and receptive language was weaker when adjusting for co-occurring expansions (ES = -0.34). Both types of directives were associated with poorer receptive *and* expressive language scores in adjusted models at 36- and 48-

months (e.g. unsuccessful directive and 48-month receptive language, ES = -0.66). FC was positively associated with 24-, 36- and 48-month language scores in adjusted models (e.g. receptive language at 24-months, ES = 0.21, at 48-months, ES = 0.18). Interaction analysis showed the negative association between successful directives and 24-month receptive language existed primarily in poorly-connected dyads with low FC levels.

Conclusions & Implications. These findings illustrated the effects of the combined interaction between different maternal communicative behaviours and features of the interaction itself on child language development, and the need to consider both in research and practice. Whilst more intrusive directives were associated with poorer language scores, this association attenuated when adjusting for co-occurring responsive expansions, and the association was strongest for children in lower quality interactions. This work may inform clinical practice, by helping clinicians target the most appropriate communicative behaviours for specific mother-child dyads.

What this paper adds

What is already known on this subject?

Developmental language disorder (DLD) is a common childhood disorder, associated with educational, health and social difficulties.

Responsive and intrusive maternal communicative behaviours contribute to children's language development, are modifiable, and therefore can be targeted in interventions.

The quality of the mother-child interaction forms the foundation on which language skills develop, and is co-constructed by the mother and the child.

What this study adds?

Maternal directives were associated with poorer concurrent and later language in slow-to-talk children. Associations were not evident for missed-opportunities or praise.

Maternal expansions, known to facilitate language development, were protective against the negative association between directives and language outcomes.

The quality of mother-child interaction and child language abilities were positively associated.

The negative association between directives and language outcomes was primarily observed when mothers and children were poorly connected to each other.

Clinical implications of this study

The potential to assist clinicians in targeting the specific maternal communicative behaviours that may be most appropriate for specific mother-child dyads.

The importance of promoting high quality interactions as well as teaching specific communicative behaviours in interventions.

Introduction

Language proficiency is a foundation skill for optimal child development. However, between 7% and 20% of children in the pre-school and early school years experience language difficulties (Norbury *et al.* 2016; Reilly *et al.* 2010). Developmental Language Disorder (DLD) is associated with negative outcomes, including poor literacy, academic achievement, and psychosocial problems that can resonate into adulthood (e.g. Beitchman *et al*. 2014). Thus, considerable effort is being expended to understand how to help children at risk.

Language develops through a complex interplay between biology and the environment (Bishop *et al*. 2016). However, biological and environmental factors associated with early language outcomes (e.g. Morgan *et al*. 2015) only explain up to 20.9% of the variability in 48-month-old language outcomes (Reilly *et al*. 2010). This suggests additional factors must be at play. Parent-child interactions represent a rich area for investigation. Studies from the typical and atypical child development literature suggest early interactions are critical to shaping and enhancing language development (Guralnick *et al.* 2008; Hart and Risley, 1995; Roberts and Kaiser, 2011; Rowe, 2012).

Investigations into the quantity and quality of parental input during parent-child interactions (Hart and Risley, 1995; Huttenlocher *et al.* 2010; Rowe, 2012) have supported the social interactionist perspective that children learn language during parent-child interactions (Bruner, 1983). Hearing fewer total and fewer diverse words leads to compromised expressive vocabulary at school-entry, which can have lasting impacts on children's language, literacy and academic trajectories (Rowe, 2012). Specific maternal and interactive communicative behaviours that have been investigated in relation to language learning will be discussed below.

Maternal communicative behaviours

Maternal communicative behaviours characterised as being responsive to the child, such as expansions and imitations, have been found to be associated with better language outcomes in population-based samples (e.g. Levickis *et al.* 2014; Masur *et al*. 2005). These behaviours are often the focus of parent-implemented language interventions (Roberts and Kaiser, 2011). Different aspects of maternal input matter at different ages and language abilities, so maternal use of a behaviour beyond an optimal age might indicate a mother-child dyad requiring help. Rowe (2012) revealed how the quantity of maternal words at 18-months, diverse and sophisticated vocabulary at 30-months, and decontextualised language at 48-months were associated with subsequent language skills.

Whilst it is generally accepted that maternal communicative behaviours influence child language, we will explore behaviours for which evidence of the nature of these associations is limited. This information could inform language interventions which target modification of parental behaviours. The behaviours considered were praise, missed-opportunities, and directives.

Praise

Maternal praise might contribute to a warm environment conducive to language-learning, yet to our knowledge, the associations with child language outcomes have not been investigated. A recent RCT of an intervention to improve language outcomes in children with conduct problems (n=60, aged 12-15 months) targeted parental behaviours, including praise (Bagner *et al.* 2016). Children receiving the intervention had better expressive language skills six-months post intervention compared with children receiving standard care. However, the study did not examine whether this improvement was mediated via improved parental behaviours, therefore we cannot conclude that parental praise was associated with better language scores.

Missed-opportunities

Since social feedback within interactions is important for early word-learning (Bedford *et al*. 2013), children's language development may be negatively impacted if their parents frequently miss opportunities to respond to them. Children may fail to see how their communication relates to parental responses, or how interactions comprise turn-taking sequences. Frequent missed-opportunities may ultimately dampen children's motivation to interact. Reasons for missed opportunities may include children with poor language skills using less salient communicative signals, and parents who are less engaged not noticing their children's communication attempts.

Directives

Maternal directives have been studied for decades, but evidence for their association with language development remains inconclusive. Mothers of children at risk of DLD (e.g. with early expressive language delay (e.g. Paul and Shiffer, 1991); neurodevelopmental disorders (e.g. Blacher *et al.* 2013; Crawley and Spiker, 1983); and low birthweight, (e.g. Landry *et al.* 1997) are reportedly more directive than mothers of typically developing children. However, whether the directives contribute to the language difficulties, or whether they are appropriate parental adaptations to the children's characteristics is uncertain (Hudry *et al*. 2013; Marfo, 1990).

Directives have been found to be associated with poorer language outcomes (e.g. Masur *et al.* 2005), better language outcomes (e.g. Akhtar *et al.* 1991), and to have no association with language (e.g. Tomasello and Todd, 1983). This is likely due to the heterogeneity in participant ages and definitions of directives used between studies, and the failure to consider the interactional context in which directives were used (Marfo, 1990). A renewed investigation is warranted to clarify their role.

Distinctions have been made between types of directives, specifically between 'following' or 'supportive' directives, and 'leading' or 'intrusive' directives (Akhtar *et al*. 1991). Supportive directives, which follow into the child's focus of attention, were not found to be associated with language outcomes in this sample (Levickis *et al*. 2014). However, intrusive directives, which lead children away from their focus of attention, have yet to be investigated in this sample. These might be associated with poorer language outcomes because they deplete children's immature attention and cognitive systems and disrupt the flow of the interaction (Akhtar *et al*. 1991; Landry *et al*. 1997; Masur *et al*. 2005; Tomasello and Todd, 1983). Directives which children follow may be less detrimental to language learning than those not followed because children can map their parents' words on to their new focus, as has been found with labels (Shimpi and Huttenlocher, 2007). Frequent unsuccessful directives might be indicative of a child with, or at risk of DLD, or a parent needing help to support their child.

The investigation into directives and language development could be further enriched by considering their association alongside co-occurring parental responsive behaviours. Attachment theorists argue that responsivity and directiveness are orthogonal characteristics, suggesting that directives should not affect the positive association between responsive behaviours and language or vice versa (Marfo, 1990). This has received partial support from studies using global parenting ratings (Crawley and Spiker, 1983; Pungello *et al.* 2009), but has yet to be tested using specific parenting behaviours. If the association between directives and language outcomes is altered by responsive behaviours this will have implications for the content and focus of parent-implemented interventions.

Mother-child interactive behaviours

The elements of parent-child interaction that are important to language development are much broader than maternal communicative behaviours alone. Parenting is bidirectional, as parents and children respond to each other's cues, signals and competencies (e.g. Guralnick *et al*. 2008). Bidirectionality is central to the transactional model of parenting, which explains that parent and child cannot be viewed as entirely independent of each other (Funamoto and Rinaldi, 2015; Sameroff, 2009). Depending on their propensity and skills, parent and child may unconsciously create and maintain an environment either more or less conducive to language-learning (Alston and James-Roberts, 2005). Responsive parents may motivate children to engage in stimulating exchanges (Pungello *et al*. 2009), and responsive children may increase parental response opportunities. In contrast, intrusive parents might disrupt language-learning by distracting or inhibiting children, and children with ambiguous or infrequent communication might provide fewer response opportunities. In this way, parents and children co-construct the foundation on which the children's language skills are built (Hirsh-Pasek *et al.* 2015).

Fluency and Connectedness

A more comprehensive investigation of how mother-child interactions are associated with language development would benefit from including a measure of the interactive dyad itself. Feasibly, such a measure might capture an aspect of the interaction missed by individual behaviours (Funamoto and Rinaldi, 2015). We selected 'Fluency and Connectedness' (FC), a measure of interaction quality that captures the flow and cohesion between mother and child, and how well they use verbal and non-verbal acts to stay on topic, orchestrate and sustain turn-taking (Adamson *et al.* 2012). The benefit of using FC over a global parent-child interaction measure is that it has strong theoretical links to language development, rather than to general child development (Mahoney *et al*. 1996). Indeed, a

study of low-income mothers and their two-year-olds (n=60) found FC was more strongly associated with expressive language skills one year later than either the number of words spoken by the mother, or a global rating of parental sensitivity. This suggests FC captures aspects of language facilitation within mother-child interactions (Hirsh-Pasek *et al*. 2015).

We hypothesised that FC might be associated with language abilities, and may also modify the effect of maternal behaviours on language outcomes. This would have implications for maximising the impact of interventions, for example, by informing how best to weave maternal input "into the fabric of early caregiver-child interactions" (Hirsh-Pasek *et al*. 2015, p. 1072).

Purpose of the current study

The current study used a community-derived sample, identified as slow-to-talk at 18-months-old, to investigate the association between language development and maternal missed-opportunities, praise, and directives, and mother-child interaction quality. This sample is of clinical interest due to its hypothesised risk of DLD. Specifically, the study aimed to determine,

1. whether missed-opportunities, praise, successful and unsuccessful maternal directives, and interaction quality (FC) at 24-months-old were associated with expressive and receptive language scores at 24-, 36- and 48-months-old;
2. whether the association between maternal directives and language development changed alongside a co-occurring maternal responsive behaviour; and
3. whether the cross-sectional associations between maternal communicative behaviours and language scores were modified by interaction quality (FC).

Methods

Participants

This study is nested within *Let's Learn Language,* a cluster randomized-controlled trial (NHMRC #384491) within a population-based survey (Wake *et al.* 2011). Parents of 12-month-olds attending their well-child check-up in three of Melbourne's 31 local government areas were invited to participate. 1,217 completed a baseline questionnaire. Exclusion criteria were developmental delay, major medical condition, suspected autism spectrum disorder (ASD), and parents with insufficient English to complete questionnaires at grade 6 (11-12 years-old) reading level.

At 18-months-old, 93.5% (n=1,138) completed a parent-reported expressive vocabulary screen (Roy *et al.* 2005). Children scoring ≤ 20th percentile based on the population norms (n=301, 26.4%) were eligible for the trial of a low-intensity parent-toddler language promotion programme. At 48-months-old, participants were invited into a subsequent language intervention trial, *Language for Learning* (NHMRC #60740) (Wake *et al*. 2012). Ethical approval was from the Royal Children's Hospital Human Research Ethics Committee (#30011). Because there were no evident differences in language outcomes between the intervention and control groups at ages 24 and 36 months (Wake *et al.* 2011), the sample was pooled for the current study.

Informed consent was received from 202 families for this study. Four children were excluded because they were diagnosed with ASD at 3-4 years-old, and one was excluded because the grandmother participated in the free-play session.

Measures

Language skills were assessed at home at 24-, 36- and 48-months-old. The Preschool Language Scale (PLS-4) (Zimmerman *et al.* 2002), a directly-assessed language measure for children from birth to 6-years, was used at 24- and 36-months-old. It yields norm-referenced scores for auditory comprehension (receptive language) and expressive communication. The Clinical Evaluation of Language Fundamentals Preschool Edition (CELF-P2) (Semel *et al.* 2006) was used at 48-months-old. It yields norm-referenced scores for receptive (sentence structure, concepts and following direction, and basic concepts subtests) and expressive language (word structure, expressive vocabulary and recalling sentences subtests). The PLS-4 and CELF-P2 standard scores are each mean (M) 100, and standard deviations (SD) 15. The measure changed at 48-months when participants joined a subsequent trial, *Language for Learning* (Wake *et al.* 2012), to harmonise measures between the studies. See study protocols for methodology details (Wake *et al*. 2011, 2012).

During the 24-month-old visit, mother and child were video-recorded playing together for 15-minutes. The mother was asked to play with her child as she normally would, using a doll and a barnyard. The primary rater (LC) used Observer® XT software (Noldus, 2008) to code the maternal communicative behaviours (praise, missed opportunities, successful and unsuccessful directives). The first and last 2.5 minutes of each video-recording were discarded as 'warming-up' and 'winding-down' time. LC logged each behaviour observed during the middle 10-minutes. Observer® XT calculated the total number and rate per minute for each behaviour. Maternal responsive communicative behaviours (expansions, imitations, responsive questions, supportive directives and labels) had been previously coded by PL in an earlier study (Levickis *et al. 2014*). The coding scheme for all maternal communicative behaviours is shown in Table 1.

[TABLE 1: Maternal Communicative Behaviours Coding Scheme]

After coding the maternal behaviours, the middle 5 minutes of the videos were observed, and the dyad's Fluency and Connectedness rated on a 7-point scale as shown in Table 2. Rating 1 represented 'no conversation established', 4 represented 'conversation lacks smoothness, appears to be dominated by one partner', and 7 represented 'fluent and balanced conversation that is often sustained' (Hirsh-Pasek *et al*. 2015) (see Table 2). To assist in selecting the appropriate rating, the rater noted episodes of turn-taking, child initiations, shared topic, and conversation progression. For example, an interaction rated 4 typically comprised two episodes of turn-taking with a long pause between them, a small number of child initiations, and missed response opportunities by mother and/or child. An interaction rated 7 comprised several episodes of smooth turn-taking which both mother and child contributed to equally, and conversation progression e.g. cuddling doll progressed to feeding doll.

[TABLE 2: Fluency and Connectedness Coding Scheme]

Inter-rater reliability was conducted on 10% of the sample by an independent rater (JS), blind to the primary rater's coding. The primary rater (LC) re-coded 10% of the sample to calculate intra-rater reliability. Reliability for the maternal behaviours was determined by calculating intra-class correlation random effects models for each behaviour, and ranged from .994 to .999 for intra-rater and .987 to .997 for inter-rater reliability (see Table 3). Reliability for FC was calculated using kappa to control for chance agreement (Cohen, 1960). Intra- and inter-rater kappas were .86 and .64 respectively in unweighted tests, with all discrepancies within one point of each other, as considered acceptable by the scale developers (Adamson *et al*. 2012).

Potential confounders of language development identified *a priori*, gender, birthweight, birth-order, parental education, maternal age, and neighbourhood disadvantage measured by the Socioeconomic Indices for Area (SEIFA) disadvantage score (ABS, 2001),

were collected in questionnaires completed between child ages 12- and 48-months-old. Sample characteristics are shown in Table 3.

[TABLE 3: Sample characteristics]

Analysis

Preliminary analyses examined linearity between communicative behaviours and language scores. Likelihood ratio tests compared regression models where behaviours were modelled as categorical (quartiles) and continuous, to models including continuous terms only. All *p*-values were >.05, providing no evidence against linearity, so analyses used continuous terms. Language scores were analysed as continuous variables, rescaled to *z*-scores (M=0, SD=1); maternal behaviours and FC were analysed as continuous variables.

The associations between communicative behaviours and expressive and receptive language scores at 24-, 36- and 48-months-old were examined using unadjusted linear regression (Aim 1). Potential confounders (described above) were added to determine whether the associations remained after adjustment. The final adjusted model examining the associations with 36- and 48-months-old language scores additionally included 24-month-old language scores (receptive/expressive as appropriate).

Next, Pearson's correlation coefficients between all communicative behaviours were examined to select the behaviours to investigate for Aim 2. That is, to investigate whether the association between directives and language scores changed alongside a co-occurring responsive behaviour. A responsive and directive behaviour were selected that were weakly correlated to avoid collinearity.

Effect modification, whereby the effect of maternal behaviours on language scores differed by interaction quality, was examined in the cross-sectional models where there was evidence of an association in the unadjusted model (Aim 3). FC × maternal behaviour was

added as an interaction term and likelihood ratio tests compared models with and without interaction. Since it can be difficult to observe subtle interaction effects (Kirkwood and Sterne, 2003), further analysis was undertaken using simple slopes (UCLA, Statistical Consulting Group). Predicted 24-month-old language scores were fitted for the maternal behaviour, holding the interaction term constant at each FC level (1-7) to illustrate how the association changed over the full range of interaction quality.

Results

Just over half (52.3%) of the participants were male, 37.1% were first-born, and 9.6% lived in a household where a language other than English was spoken. Despite efforts to recruit across high, medium and low socio-economic areas, the sample was slightly more socially advantaged (M=1026.5, SD=53.3) than the Australian population on average (M=1000, SD=100), indicated by the SEIFA score (see Table 3). This study comprised 197 of the original 251 families video-recorded. Differences were not evident between the 197 participants who were in this study compared with the remainder of the 251 who were video-recorded, except for maternal age (mothers in the study-sample were 1.3 years older, 95% CI 0.46, 2.14).

Maternal and interactive behaviours are summarised in Table 4. Praise occurred most frequently (approximately once every minute), missed-opportunities and directives occurred every 2-3 minutes. The mean FC rating of 3.82 indicated that, on average, interactions lacked smoothness, were dominated by one partner (usually, although not always, the mother), and were not strongly cohesive.

[TABLE 4 –Summary statistics of maternal and interactive behaviours]

Aim 1: Maternal behaviours, interaction quality and language outcomes

There was no evidence that missed-opportunities or praise were associated with language scores at any age if examined across the continuum of language scores in the unadjusted models or the models adjusted for confounders (see Table 5 – coefficients are reported for models adjusted for confounders, and for models adjusted for confounders plus 24-month language score. Unadjusted models are not reported to reduce the size of the tables).

The data were then dichotomised into low (scoring ≥1.25 SD below the normative mean) versus typical expressive language groups (as per Reilly *et al*. 2010) using the 24-month-old expressive language scores (n=27 low expressive language, n=168 typical expressive language). The mean rate of missed-opportunities was significantly higher for children with typical expressive language scores than for those with low expressive language scores (M = 0.40/min versus M = 0.22/min, $p = 0.023$). There were no evident differences for praise rates between participants with low expressive language scores at 24-months and those with typical expressive language scores. No further analyses were undertaken for missed-opportunities or praise.

Successful directives were associated with lower 24-month-old receptive and expressive language scores in the unadjusted models but not after adjusting for confounders, and with lower 36- and 48-month-old receptive and expressive language scores in the unadjusted *and* adjusted models. For example, one additional successful directive was associated with 0.45 SD lower receptive language score at 36-months-old [95% CI -0.84, -0.06]. After adding 24-month-old language scores to the models, the association with 36-month-old language scores attenuated, but the 48-month-old associations remained.

Unsuccessful directives were associated with 24-month-old receptive language after adjusting for confounders. Each additional unsuccessful directive was associated with an

estimated 0.41 SD lower receptive language score [95% CI -0.74, -0.08], but an association was not evident for 24-month-old expressive language. Unsuccessful directives were associated with poorer 36- and 48-month-old receptive *and* expressive language scores after adjusting for confounders. For example, each additional unsuccessful directive was associated with an estimated 0.37 SD lower receptive language score at 36-months-old [95% CI -0.69, -0.04] and 0.66 SD lower score at 48-months-old [95% CI -0.99, -0.33]. These associations remained after adding participants' 24-months language scores to the adjusted models (Table 4). The magnitude of the associations with 36- and 48-month-old language scores was similar for successful and unsuccessful directives.

FC was positively associated with expressive and receptive language scores at 24- and 36-months-old after adjusting for confounders (e.g., 24-months-old receptive language, ES= 0.21, 95% CI [0.12, 0.29]), but with only receptive language scores at 48-months-old (ES=0.18, 95% CI [0.08, 0.27]). The association with 36- and 48-month-old language was no longer evident when 24-month-old language scores were added to the models.

[TABLE 5 – Association between maternal behaviours and interaction quality and child language scores]

Aim 2: Maternal Directives and Co-occurring Maternal Responsive Behaviour

Unsuccessful directives were selected as the intrusive maternal behaviour for this analysis as they were associated with poorer language scores at each age. They were weakly correlated with both imitations and expansions (r= -0.18, Table 6). Since expansions were previously found to have the stronger association with concurrent and later language scores than imitations (Levickis *et al. 2014*), they were selected as the responsive behaviour.

[TABLE 6 – Correlation matrix]

When expansions were included in the model, the estimated mean change in receptive language score for each additional unsuccessful directive was lower. For example, 24-month-old coefficients attenuated from -0.41 to -0.34, 36-month-old coefficients from -0.37 to -0.29, and 48-month-old coefficients attenuated from -0.66 to -0.59. A similar pattern was observed for 36- and 48-months-old expressive language scores after controlling for expansions. In contrast, the receptive and expressive language coefficients associated with one additional expansion after controlling for unsuccessful directives remained almost unchanged (e.g. 24-month-old receptive language without adjustment = 0.48, after adjustment = 0.47) (see Table 7). The estimated associations for expansions, without adjusting for directives, are included in Table 7 for comparison.

[TABLE 7]

Aim 3: Maternal Behaviours in the Context of Mother-Child Fluency and Connectedness

Examination of FC as an interaction term in the maternal behaviour and 24-month-old language models found that a significant interaction effect was only evident for the association between successful directives and receptive language (Table 8). For each point higher FC rating, the predicted slope became shallower by 0.28 SD (95% CI [0.03, 0.54], p=0.025). Thus, in dyads with lower levels of FC, the estimated mean difference in receptive language score associated with each additional successful directive was more substantive than in dyads with higher FC. That is, the negative association between successful directives and language scores was stronger in poorly-connected dyads.

[TABLE 8 – Interaction effects]

Further investigation of effect modification using simple slopes suggested that the negative association between successful directives and receptive language primarily existed for dyads with no or low FC (rated 1-3) (see Figure 1).

[FIGURE 1]

Simple slopes of effect modification by FC were examined for the associations between 24-month language scores and expansions, and between 24-month language scores and unsuccessful directives (with and without controlling for co-occurring expansions). As the initial interaction analysis revealed no evidence of statistically significant interaction effects by FC for these behaviours (as shown in Table 8), these additional simple slope results are included in a supplementary figure and table to avoid over-interpretation.

[SUPPLEMENTARY FIGURE 1 AND ACCOMPANYING TABLE 1]

These findings showed consistency with those of the association between successful directives and receptive language scores, insofar as the significant associations varied by FC level. For example, in contrast to successful directives, the association between unsuccessful directives and receptive language scores was statistically significant and stronger at higher FC levels (rated 3-7). The associations between expansions and receptive and expressive language scores were significant at levels 1-6, but weakened at higher FC levels.

Discussion

This study highlights the importance of considering maternal behaviours and the interactional context for ongoing language learning amongst children with low expressive language at 18-months. We explored the association between maternal behaviours and interaction quality at age 24-months and language outcomes at 24-, 36- and 48-months. Nuanced associations between language scores and directives which a child did or did not follow were found. Directives which the child did not follow were associated with poorer 24-month receptive language skills, yet both types were associated with poorer 36- and 48-

month expressive and receptive language skills. These associations were weaker when maternal expansions were considered, revealing how combinations of maternal input may be differentially associated with language-learning. Mothers of toddlers with expressive language difficulties at 24-months missed fewer response opportunities than mothers of children with typical language, suggesting mothers adapted to their children's poorer expressive skills. Higher fluency and connectedness were associated with better child language skills, and modified the effects of maternal successful directives. The negative association between successful directives and 24-month-old receptive language scores was only evident for parents and children with low fluency and connectedness.

Aim 1: Maternal behaviours, interaction quality and language outcomes

In this study, mothers were more likely to respond (verbally or non-verbally) to communicative acts of toddlers with poorer expressive language abilities than those with typical language. These mothers may have adapted their behaviour to their children's delayed skills and became more vigilant of their communicative attempts. This explanation would be in line with reports suggesting that parents of children with developmental difficulties are highly responsive to child initiations and opportunities to interact, adjusting their social communication over time to support their children's level of development (e.g. Guralnick *et al*. 2008). We found no evidence that more maternal praise was associated with higher language scores This might have been due to the unstructured task lacking contextual "draw" (Blacher *et al*. 2013) to elicit the levels and types of praise meaningful to the child, and the broad definition employed. Further research is therefore required. Whether intervention-specific praise has therapeutic value also requires investigation.

Our findings that unsuccessful intrusive directives were associated with lower concurrent receptive language scores independent of confounders supports previous

investigations that have found directives which lead children's attention are associated with poorer language skills (Akhtar *et al*. 1991; Masur *et al*. 2005; Tomasello and Todd, 1983). Successful directives were also associated with poorer receptive language, but only before adjusting for confounders. This finding is at odds with our hypothesis that successful directives might provide a subsequent language-learning opportunity, based on Shimpi and Huttenlocher's (2007) research into maternal labels. Perhaps directives are more likely to be unsuccessful than successful in children with lower receptive language skills because they may fail to understand the directives. Mothers of children with low receptive language may have repeated directives until their children responded, resulting in a stronger association between receptive language scores and unsuccessful directives than between receptive language scores and successful directives. Whilst this could indicate a mismatch between the level at which the mother was targeting and the child's competency level, it is also feasible that it was appropriate and adaptive for slower language-learners. By usually referring to the immediate environment and so having high referential transparency, directives conceivably could facilitate word-learning for children with poor language-learning skills. The negative association could reflect the fact that mothers of children with low language adapt by using more directives than mothers of those with typically developing language.

Both successful and unsuccessful directives used at 24-months-old were associated with poorer receptive *and* expressive language scores at 36- and 48-months-old. In the case of 48-month language scores, this association was evident even after adjusting for 24-month-old language scores. This might be explained by slow language learners continuing to learn language slowly and falling behind their peers at 48-months. Another possibility is that mothers' continued use of directives (assuming directive use at 24-months is indicative of ongoing directive use) moves from being appropriately adaptive to being maladaptive, having a detrimental effect on language abilities at 36- and 48-months. Cumulatively, directives may

limit children's opportunities for conversation, disrupt the children's attention (Tomasello and Todd, 1983), fail to stimulate lexical hierarchies and representations in their minds (Diaz *et al.* 1991), and result in less effective storage and retrieval from their lexicon, resulting in poorer language development. However, we need repeated observations of directives over time to determine whether maternal directive use at 24-months is indicative of directive use at later time points.

The final behaviour, fluency and connectedness (FC), assessed the quality of the mother-child dyadic interaction We found that more fluent and connected interactions were associated with higher concurrent and later expressive and receptive language scores, expanding upon previous findings regarding expressive language skills only in a younger sample (Hirsh-Pasek *et al.* 2015). Interactions where the mother and child are poorly connected may provide a sub-optimal language-learning foundation, whilst well-connected interactions may provide a strong scaffold within which the child can learn, practice and build upon new words. In the absence of such a scaffold, parents' words may pass by "like background noise", having no impact on child learning (Hirsh-Pasek *et al.* 2015, p.1081).

It is unlikely that the association between child language skills and FC is unidirectional. Better parental language skills likely facilitate their capacity to engage with their children, and better child language abilities likely facilitate children's capacity to engage and connect with their parents (Hudry *et al.* 2013). Poorer child language skills in contrast are associated with lower rates of initiation and responsiveness (Conti-Ramsden *et al.* 1995), which impact children's ability to engage with, and be engaged by, their parents. Even with parents' best intentions, poorer child language skills may restrict the degree of flow possible during an interaction. This is illustrated by the association between FC and later language scores attenuating once concurrent language scores were included in the models; children's

24-month-old language skills likely contributed to how well they interacted with their mother, as well as their later language skills.

Aim 2: Directives and co-occurring expansions

The negative association between directives and language scores weakened in the presence of expansions, whilst the positive association between expansions and language scores was maintained. This provides empirical support for the idea that directiveness does not necessarily occur at the expense of the facilitative aspects of responsivity (Marfo, 1990). Unlike directives, expansions provide enriched linguistic input in the form of greater semantic and phonological information about words (Hoff, 2003), resulting in more robust lexical hierarchies. The language-learning opportunity afforded to the child by these expansions may have been greater than any deficits associated with unsuccessful directives.

Aim 3: Maternal behaviours in the context of mother-child interaction quality

The final part of this study considered whether the dyadic environment in which communicative behaviours were used modified their association with language scores. As Ratner (2013) proposed, individual differences in adult-child dyadic interactions could "create differences in how children best exploit their language environments to learn" (p214). Our findings partially support this. The negative association between successful directives and 24-month-old receptive language scores was strongest in minimally-connected dyads (rated 1-3), whilst there was no evidence of this association in well-connected dyads (rated 4-7).

Children in minimally-connected dyads may be particularly susceptible to the negative effects of directives on language learning, whilst those in well-connected dyads may be buffered from them. Alternatively, mothers may use directives to engage children who have difficulties initiating and/or sustaining a connection, as suggested by Hudry *et al*.'s

(2013) findings of parent-child interaction styles among young children with ASD. The fact that these directives were successfully followed by the child points to the success of the mothers' strategy. This success may reinforce the mothers' use of directives. Maternal on-going use of directives may continue to be adaptive, as long as the child is learning language within their zone of proximal development (Vygotsky, 1978). However, since directives typically do not foster turn-taking or conversation, their continued use may restrict a dyad from developing along the FC scale once the child's language learning is ready to be extended. This may mean mother and child perpetuate a pattern of interaction that is sub-optimal for language-learning, and continue to function in a lower quality interactive system.

Whilst there was no evidence for a significant interaction effect among the other associations examined, exploratory simple slope analysis revealed how the connectedness between mother and child might modify the associations between other maternal communicative behaviours and child language learning. This provides a more nuanced understanding of the developmental precursors of children's language (Hirsh-Pasek *et al*. 2015). Repeated measures of interaction quality are needed to explore these issues in more detail, along with repeated measures of maternal behaviours to monitor change or stability in use over time. The resulting rich understanding may inform which parenting behaviours might be most appropriately targeted in dyads of different qualities and at different stages of development.

Strengths and limitations

The study sample included children with low expressive vocabulary at 18-months-old and thus limits the generalisability of the findings. This is important given that subsequent studies revealed that early expressive vocabulary delays alone do not accurately predict later language difficulties (e.g. Reilly *et al*. 2010). This sample contained a similar percentage of

children with language difficulties at 36- and 48-months-old as found in a community population sample (Reilly *et al.* 2010). Nevertheless, since studies have identified differences in the interactions of carers of typically developing children compared to those of children with DLD (e.g. Conti-Ramsden *et al.* 1995), there may be differences in the maternal behaviours used in this sample compared to either a general population or a late-talker sample (usually defined by 24-months-old language skills).

Our ability to evaluate direction of effects was restricted by having no direct measures of the child's contributions during the interaction (e.g. interest levels, locomotion, initiations), and only having a single observation of the interaction. A recent examination of treatment mechanisms for an RCT for children with ASD incorporated three parent-child observations over 12-months (Pickles *et al.* 2015). These repeated observations enabled the researchers to use mediation techniques to uncover causal relationships between changes in parental and child behaviours. Repeated observations in studies such as the current one might allow similar techniques to be used to evaluate the direction of effect between parental and interactive behaviours and child language scores. Of course, the observations would need to take place within a sufficient timeframe for developmental changes to occur. As noted earlier, this approach could also reveal how parental and interactive behaviours change over time.

Further limitations include the relatively socially-advantaged sample. This means dyads with higher rates of missed-opportunities and lower rates of praise, due to experiencing greater stressors associated with economic and social adversity, might be under-represented. Changing from the PLS-4 to the CELF-P2 at 48-months, which is not unprecedented or avoidable in longitudinal studies, was not ideal as it introduced the potential for non-equivalence. The potential for measurement error also existed due to observed maternal behaviours potentially not being representative of typical, non-observed behaviour (Uziel, 2010). Further, a measure of maternal language ability would have enabled us to examine

how this might be associated with maternal behaviours used and the FC measure. Finally, the inter-rater reliability for the FC scale was moderate at 0.64. Although all ratings were within one point of each other, as considered acceptable by the developers of the scale (Adamson *et al.* 2012; also see Bakeman and Quera, 2011), refinement would be necessary for use in future studies.

The strengths of this study include: a large sample size relative to other studies in this area; recruitment from the community rather than concerned families who present to clinics; the development of a reliable coding scheme that can be implemented with minimal cost and thorough training, and; the combined consideration of maternal behaviours and the interactional context on language development.

Practical implications

The findings have practical implications for early language promotion and intervention strategies. Firstly, addressing how caregivers interpret their child's response to directives may be important for changing their communicative behaviours. For example, parents who frequently use directives might benefit from learning to use other strategies which might break maladaptive interaction patterns. Secondly, promoting parental behaviours associated with better language development (e.g. expansions), rather than advising against certain behaviours (e.g. directives) might be an effective strategy for clinicians and one that is more acceptable to parents.

A third clinical implication is that it may be important to target interaction quality in interventions alongside teaching specific communicative behaviours, as has been recommended previously (Hirsh-Pasek *et al.* 2015; Roberts and Kaiser, 2011). The FC measure may be a practical tool for clinicians. However, research is required to determine the components of this single item, with the aim of isolating the skills needed by parent and child

to participate at each FC level; to determine how clinicians can best coach parents to use these skills; and how parents can teach their children to use these skills. This includes investigating the appropriate dosage, that is, what intensity and frequency is required to influence children's language outcomes (Dunst *et al.* 2014).

Finally, our finding that interaction quality modified the association between successful directives and poorer receptive language outcomes, whereby the association was strongest in poorly connected dyads whilst not evident in well-connected dyads, has implications for the design of intervention strategies. It supports the idea that interaction quality may form the foundation of future language learning (Hirsh-Pasek *et al.* 2015) and differences in dyadic interaction may create differences in how children use their environmental inputs (Ratner, 2013). Coaching caregivers about fostering high quality interactions might be best integrated throughout all intervention sessions. Parents of children with poorer language could benefit from support to recognise poorly-formed communication bids from their child and provide rich and individually-tailored language stimulation. In cases where the dyads are already well-connected the potential impact of these strategies may be lower, as there will be fewer opportunities for change. The FC ratings might inform clinical decision-making and be straightforward to use in a sensitive manner, both recommended prerequisites for parent-child interaction assessment to become routine practice (Mahoney *et al.* 1996). An assessment of a dyad's connectedness could assist clinicians to work with parents to foster an interactive environment that is most conducive to an individual child's learning needs.

Future research

Our findings verify the need to incorporate the bidirectional model into language development research and practice. Research should continue to investigate other

communicative behaviours and aspects of the interaction that may be associated with language outcomes at different ages and stages. It would benefit from incorporating child behavioural measures, and using repeated observations to better understand the complex parent-child transactional relationships. Research is required to design and test practical strategies to teach caregivers to engage in more fluent and connected interactions with their children, and finally whether assessing interaction quality is appropriate and helpful during a language assessment.

Conclusion

Using a sample of slow-to-talk children, the study adds to the existing literature about children's home language-learning environment in several ways. Firstly, by identifying that maternal intrusive directives, whilst being associated with poorer language scores at 24-, 36- and 48-months-old, also appear to have a weakened association with language outcomes in the presence of maternal responsive expansions. Secondly, by confirming that investigating the mother-child interactive dyad as its own entity is essential to child language research. Thirdly, by illustrating how the combined effect of different types of maternal communicative behaviours and features of the interaction itself might interact to predict child language outcomes. Most importantly, our findings contribute to the ongoing effort to generate evidence-based recommendations for clinical practice to help children with, or at risk of, developmental language disorder.

Tables and Figures

Table 1: Coding Scheme for Maternal Communicative Behaviours

Directive (Adapted from Akhtar *et al*. 1991; Shimpi and Huttenlocher, 2007)	Utterance that aims to re-direct child away from the object or activity on which they are currently visually focused to something new or different Successful: child shifts visual focus toward the goal. Unsuccessful: child does not shift visual focus.	C: Playing with truck, M: "Look in the bag!" Successful: child looks in bag Unsuccessful: child does not change focus
Praise (Adapted from Gaertner *et al.* 2008; Winsler *et al.* 1999)	Verbal or non-verbal positive evaluations of child's efforts, global characteristics, or generic positive evaluations.	"Good job!", "You're so clever!"
Missed opportunity	Mother does not respond in any way to a child's utterance after 3 secs	C: "Twuck", M: No response
Expansion (Levickis *et al.* 2014)	Mother repeats one or all of the child's preceding words and adds to the child's preceding verbalization	C: "Ball", M: "It's a red ball"
Imitation (Levickis *et al.* 2014)	Mother repeats the child's preceding vocalisation or verbalisation exactly or with a reduction in the words.	C: "Ball", M: "Ball"
Responsive question (Levickis *et al.* 2014)	Mother asks a "wh" question (e.g. "what", "when", "who"), which is immediate and dependent on the child's preceding act.	Child is playing with horse M: "What's that?"
Supportive directive (Levickis *et al.* 2014)	Mother directs or commands the child to verbalise or do an action in relation to what the child is focused on.	Child is playing with doll M: "Feed the doll"
Label (Levickis *et al.* 2014)	Mother labels an object or action, which is the focus of the child, with the label in the final position of the carrier phase.	Child is playing with a toy horse M: "That's a horse"

Table 2: Coding Scheme for Fluency and Connectedness

Fluency and Connectedness	Characterises the flow of the conversation						
	1=	**2=**	**3=**	**4=**	**5=**	**6=**	**7=**
Modified from Adamson *et al.* (2012) and Hirsh-Pasek *et al.* (2015).	No conversation established.	Interaction established but child frequently not responding.	Instances of child initiations reciprocated by mother.	Conversation lacks smoothness, appears to be largely dominated by one partner.	Shared topic throughout. Both partners engaged in relatively equal turn-taking.	Extension of interaction and play by both partners.	Fluid and balanced conversation that is often sustained.

Table 3: Sample Characteristics

Sample Characteristics		Total *n*	*n* (%) or *M* (*SD*)	
Gender, male		197	103 (52.3)	
First-born child		197	73 (37.1)	
Birthweight (*g*)		190	3380.3 (620.2)	
SEIFA index score of disadvantage		197	1026.5 (53.3)	
Maternal age at child age 12-months		197	34.3 (4.5)	
NESB		197	19 (9.6)	
In intervention arm of trial		197	100 (50.8)	
Parental education:	Not completed high school		38 (19.4)	
	Completed high school		65 (33.2)	
	Completed diploma/tertiary qual/postgrad		93 (47.5)	
Child Language Standard Scores [a]		*n*	*M* (*SD*)	Low Language *n* (%) [b]
Receptive language:	24-months-old	195	90.6 (14.0)	63 (32.3)
	36-months-old	190	98.4 (15.2)	24 (12.7)
	48-months-old	193	94.7 (14.0)	33 (17.1)
Expressive language:	24-months-old	195	91.8 (11.9)	27 (13.9)
	36-months-old	189	101.1 (14.5)	16 (8.5)
	48-months-old	192	97.7 (14.3)	26 (13.5)

SEIFA = Socio-Economic Index for Areas, NESB = Non-English-speaking background.

[a] PLS-4 at 24- & 36-months-old, CELF-P2 at 48-months-old; [b] Low language defined as scoring ≥1.25 SD below the mean on expressive and/or receptive language score

Table 4: Summary Statistics of Maternal Communicative Behaviours and Interaction Quality

Communicative behaviours (rate per min, rpm)	*n*	*M (SD), min, max*	Reliability [a]	
			Inter-rater	Intra-rater
Successful directives	196	0.41 (0.35), 0, 2.1	.987	.994
Unsuccessful directives	196	0.33 (0.42), 0, 2.4	.997	.995
Missed-opportunities	196	0.37 (0.37), 0, 1.9	.990	.986
Praise	196	0.82 (0.71), 0, 3.8	.997	.999
Fluency and Connectedness Rating (scale 1-7)	195	3.82 (1.55), 1, 7	.644	.857
Previously Coded Responsive Behaviours (rpm)	*N*	*M (SD), min, max*		
Expansions	197	0.6 (0.61), 0, 3.2		
Imitations	197	0.47 (0.48), 0, 3.3		
Interpretations	197	0.57 (0.44), 0, 2.3		
Labels	197	1.17 (0.68), 0, 4.2		
Supportive directives	197	0.6 (0.45), 0, 2.6		
Responsive questions	197	0.71 (0.53), 0, 2.7		

Note. [a] Intra-class correlation random effects for maternal behaviours; Cohen's kappa's (Cohen, 1960) for Fluency and Connectedness.

Table 5: Associations Between Maternal Communicative Behaviours, Interaction Quality and Child Language Scores at 24-, 36- and 48-months

Behaviour	Adjusted [a]				Adjusted [a] + 24m language score			
	ES [b]	95% CI	*p*	R^2	ES [b].	95% CI	*p*	R^2
Missed-opportunities								
24m Receptive	-0.11	[-0.48, 0.25]	0.547	0.14				
Expressive	0.14	[-0.23, 0.50]	0.453	0.14				
36m Receptive	-0.22	[-0.59, 0.15]	0.248	0.18	-0.18	[-0.46, 0.11]	0.229	0.50
Expressive	-0.11	[-0.48, 0.26]	0.556	0.17	-0.12	[-0.43, 0.18]	0.427	0.44
48m Receptive	0.06	[-0.33, 0.45]	0.761	0.11	0.20	[-0.14, 0.54]	0.237	0.39
Expressive	-0.09	[-0.46, 0.29]	0.645	0.16	0.01	[-0.34, 0.36]	0.939	0.35
Praise								
24m Receptive	0.17	[-0.02, 0.36]	0.075	0.16				
Expressive	0.03	[-0.16, 0.22]	0.743	0.14				
36m Receptive	0.10	[-0.10, 0.30]	0.344	0.18	-0.08	[-0.24, 0.08]	0.316	0.49
Expressive	0.06	[-0.14, 0.26]	0.532	0.17	-0.06	[-0.23, 0.11]	0.483	0.44
48m Receptive	-0.00	[-0.20, 0.20]	0.997	0.11	-0.11	[-0.29, 0.07]	0.220	0.39
Expressive	0.06	[-0.13, 0.25]	0.527	0.17	-0.01	[-0.19, 0.17]	0.939	0.35
Successful directives								
24m Receptive	-0.37	[-0.75, 0.02]	0.063	0.16				
Expressive	-0.33	[-0.72, 0.06]	0.095	0.15				
36m Receptive	-0.45	[-0.84, -0.06]	0.023	0.20	-0.22	[-0.53, 0.10]	0.177	0.50
Expressive	-0.50	[-0.90, -0.09]	0.016	0.20	-0.27	[-0.61, 0.08]	0.130	0.45
48m Receptive	-0.70	[-1.09, -0.30]	<0.001	0.16	-0.49	[-0.85, -0.13]	0.008	0.42
Expressive	-0.74	[-1.12, -0.36]	<0.001	0.23	-0.58	[-0.95, -0.22]	0.002	0.38
Unsuccessful directives								
24m Receptive	-0.41	[-0.74, -0.08]	0.015	0.17				
Expressive	-0.16	[-0.49, 0.18]	0.350	0.14				
36m Receptive	-0.37	[-0.69, -0.04]	0.027	0.20	-0.19	(-0.46, 0.08)	0.159	0.50
Expressive	-0.53	[-0.85, -0.22]	0.001	0.22	-0.41	(-0.69, -0.14)	0.004	0.47
48m Receptive	-0.66	[-0.99, -0.33]	<0.001	0.18	-0.54	(-0.85, -0.24)	<0.001	0.43
Expressive	-0.55	[-0.87, -0.22]	0.001	0.21	-0.46	(-0.77, -0.14)	0.005	0.38
Fluency & Connectedness								
24m Receptive	0.21	[0.12, 0.29]	<0.001	0.24				
Expressive	0.10	[0.01, 0.19]	0.034	0.16				
36m Receptive	0.19	[0.10, 0.28]	<0.001	0.25	0.06	(-0.02, 0.13)	0.151	0.50
Expressive	0.15	[0.06, 0.24]	0.002	0.22	0.03	(-0.05, 0.11)	0.476	0.44
48m Receptive	0.18	[0.08, 0.27]	<0.001	0.17	0.08	(-0.01, 0.17)	0.066	0.40
Expressive	0.06	[-0.03, 0.15]	0.208	0.17	-0.02	(-0.11, 0.07)	0.673	0.34

Note. CI = confidence interval. Language measured using PLS-4 at 24- and 36-months, CELF-P2 at 48-months, *z*-scores; [a] Adjusted for child gender, birthweight, birth-order, treatment group, neighbourhood disadvantage score (SEIFA), parental education,

maternal age; [b] ES = effect size: interpret as the average SD difference in language score for 1-rate per minute higher communicative behaviour, or one-point higher rating on FC

Table 6: Pearson's Correlation Matrix Between Maternal Behaviours and Interaction Quality

Behaviour *r*-value *p*-value	**1:**	**2:**	**3:**	**4:**	**5:**	**6:**	**7:**	**8:**	**9:**	**10:**	**11:**
1. Praise	1										
2. Missed opportunities	-0.28 <0.001	1									
3. Successful directives	0.13 0.078	-0.1 0.167	1								
4. Unsuccessful directives	0.04 0.538	-0.17 0.015	0.46 <0.001	1							
5. Expansions	0.02 0.784	-0.1 0.183	-0.19 0.008	-0.18 0.012	1						
6. Imitations	0.01 0.914	-0.07 0.331	-0.16 0.028	-0.18 0.014	0.58 <0.001	1					
7. Interpretations	0.1 0.183	-0.03 0.708	-0.16 0.023	-0.18 0.013	0.28 <0.001	0.19 0.01	1				
8. Labels	0.05 0.484	-0.25 <0.001	0.001 0.993	-0.01 0.9	-0.18 0.01	-0.07 0.35	0.07 0.327	1			
9. Supportive directives	0.33 <0.001	-0.2 0.006	0.25 0.001	0.16 0.024	-0.07 0.304	-0.02 0.774	0.02 0.8	0.1 0.162	1		
10. Responsive questions	0.14 0.057	-0.11 0.126	-0.14 0.052	-0.09 0.2	0.25 <0.001	0.28 <0.001	0.03 0.633	-0.01 0.849	-0.01 0.879	1	
11. Fluency and Connectedness	0.11 0.128	-0.12 0.086	-0.06 0.41	-0.24 0.001	0.45 <0.001	0.35 <0.001	0.38 <0.001	0.08 0.29	0.07 0.354	0.16 0.027	1

Note: Items 1-10 are rate per minute values, item 11 is a rating value from 1-7

Table 7: Associations Between Co-occurring Unsuccessful Directives and Expansions, and Language Scores at 24-, 36- and 48-months

	Adjusted [b]				Adjusted [b] + 24m language score			
	ES [c]	95% CI	*p*	R^2	ES [c]	95% CI	*P*	R^2
24m Receptive [a] Directive	-0.34	[-0.66, -0.03]	0.034	0.24				
Expansion	0.47	[0.25, 0.69]	<0.001					
24m Expressive: Directive	-0.08	[-0.40, 0.23]	0.608	0.25				
Expansion	0.56	[0.33, 0.78]	<0.001					
36m Receptive: Directive	-0.29	[-0.60, 0.02]	0.066	0.28	-0.11	[-0.37, 0.15]	0.421	0.52
Expansion	0.50	[0.28, 0.72]	<0.001		0.24	[0.04, 0.43]	0.016	
36m Expressive: Directive	-0.45	[-0.75, -0.15]	0.003	0.33	-0.44	[-0.71, -0.16]	0.002	0.45
Expansion	0.56	[0.35, 0.78]	<0.001		0.36	[0.15, 0.57]	<0.001	
48m Receptive: Directive	-0.59	[-0.91, -0.27]	<0.001	0.24	-0.42	[-0.71, -0.13]	0.005	0.42
Expansion	0.44	[0.21, 0.67]	<0.001		0.23	[0.02, 0.44]	0.032	
48m Expressive: Directive	-0.48	[-0.79, -0.17]	0.003	0.28	-0.47	[-0.77, -0.17]	0.002	0.35
Expansion	0.45	[0.23, 0.68]	<0.001		0.34	[0.11, 0.56]	0.004	
Coefficients for expansions without adjusting for directives, for comparison purposes								
24m Receptive	0.48	[0.25, 0.70]	<0.001	0.22				
24m Expressive	0.55	[0.34, 0.77]	<0.001	0.25				
36m Receptive	0.51	[0.28, 0.73]	<0.001	0.26	0.16	[-0.04, 0.35]	0.115	0.50
36m Expressive	0.59	[0.37, 0.80]	<0.001	0.29	0.26	[0.06, 0.46]	0.013	0.46
48m Receptive	0.47	[0.23, 0.71]	<0.001	0.17	0.22	[-0.00, 0.45]	0.054	0.41
48m Expressive	0.48	[0.25, 0.70]	<0.001	0.24	0.27	[0.04, 0.50]	0.023	0.37

Note. CI = confidence interval. [a] Language measured using PLS-4 at 24- & 36-months-old, CELF-P2 at 48-months-old (*z*-scores); [b] Adjusted for child gender, birthweight, birth-order, treatment group, neighbourhood disadvantage score (SEIFA), parental education, maternal age; [c] ES = effect size: interpret as the average SD difference in language score for 1-rate per minute higher communicative behaviour

Table 8: Interaction Effects of Fluency and Connectedness on the Association Between Maternal Communicative Behaviours and Language Scores at 24-months

	Unadjusted			Adjusted [a]		
Behaviour	Coef.[b]	95% CI	*p* [c]	Coef.[b]	95% CI	*p* [c]
Receptive language [d]						
Successful directives	0.29	[0.05, 0.54]	0.018	0.28	[0.03, 0.54]	0.025
Unsuccessful directives	-0.18	[-0.42, 0.05]	0.123	-0.15	[-0.63, 0.95]	0.199
Expansions	-0.08	[-0.21, 0.05]	0.237	-0.06	[-0.19, 0.07]	0.366
Expansions and	-0.11	[-0.24, 0.03]	0.250	-0.08	[-0.22, 0.05]	0.430
unsuccessful directives [e]	-0.11	[-0.36, 0.14]		-0.08	[-0.33, 0.18]	
Expressive language [d]						
Successful directives	0.03	[-0.23, 0.30]	0.794	0.07	[-0.21, 0.34]	0.608
Unsuccessful directives	-0.22	[-0.47, 0.03]	0.076	-0.19	[-0.44, 0.07]	0.138
Expansions	-0.12	[-0.26, 0.01]	0.069	-0.12	[-0.26, 0.01]	0.058
Expansions and	-0.14	[-0.27, 0.00]	0.133	-0.14	[-0.27, 0.00]	0.130
unsuccessful directives [e]	-0.09	[-0.34, 0.17]		-0.06	[-0.32, 0.20]	

Note: CI = confidence interval. [a] Adjusted for child gender, birthweight, birth-order, treatment group, neighbourhood disadvantage score (SEIFA), parental education, and maternal age;

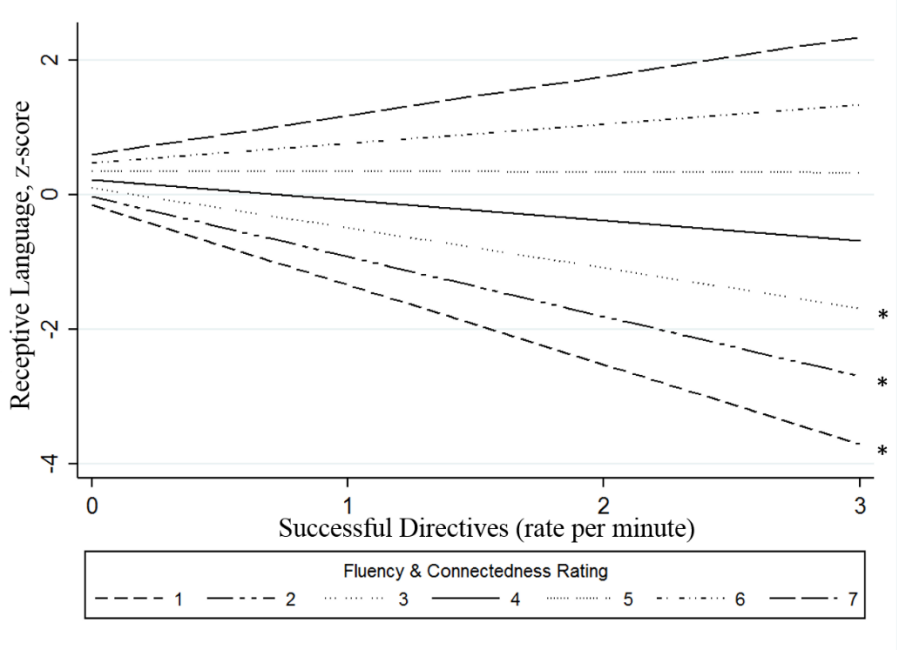
[b] interaction coefficient; [c] *p*-value for likelihood ratio test comparing regression model containing the interaction term with regression model without the interaction term.

[d] Language measured using PLS-4 at 24- & 36-months, CELF-P2 at 48-months (z-scores)

[e] Model includes both behaviours adjusted for one another: expansions and language adjusted for unsuccessful directives, and unsuccessful directives and language adjusted for expansions.

Figure 1: Simple Slopes Modelling Effect Modification by Fluency and Connectedness on the Association Between Successful Directives and Receptive Language Scores at 24-months **denotes p<0.05*

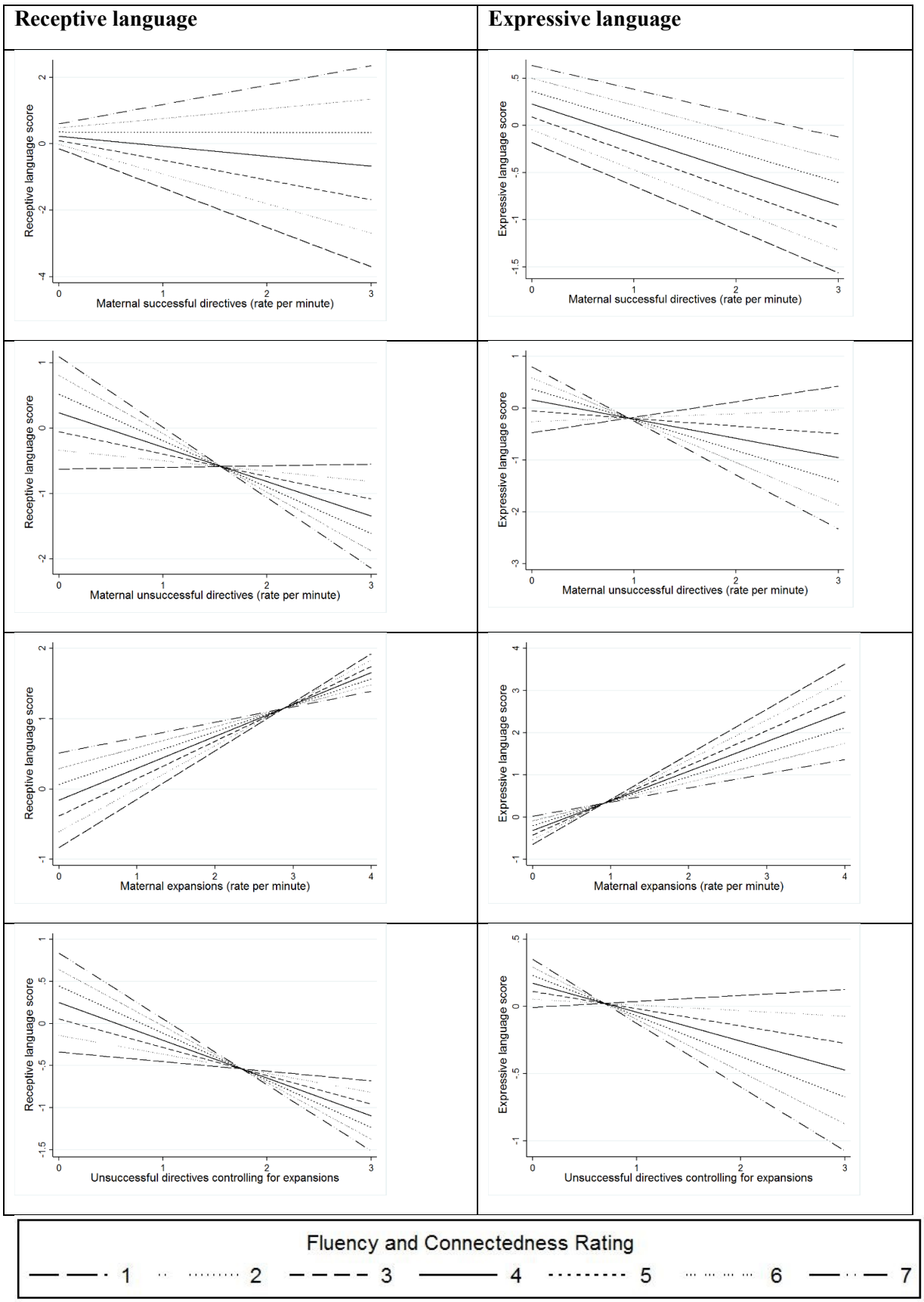
Simple Slopes Graph



Estimated Association at Each Level of Fluency and Connectedness

Fluency and Connectedness	**Receptive Language Score**		
	ES	95% CI	*p*
1	-1.18	[-1.92, -0.44]	.002
2	-0.89	[-1.43, -0.35]	.001
3	-0.59	[-0.98, -0.20]	.003
4	-0.30	[-0.67, 0.07]	.111
5	-0.01	[-0.50, 0.49]	.980
6	0.29	[-0.40, 0.98]	.410
7	0.58	[-0.33, 1.49]	.208

Supplementary Figure 1: Simple slopes for Associations Between Maternal Communicative Behaviours and 24-month Language *z*-scores by Fluency and Connectedness level



Supplementary Table 1: Simple Slopes Statistics for the Association Between Maternal Communicative Behaviours and 24-month Language Scores by Fluency and Connectedness Level (1-7)

FC [a] rating	**Receptive language [d]**			**Expressive language [d]**		
	ES [b]	95% CI [c]	*p*	ES [b]	95% CI	*P*
Successful directives						
1	-1.18	[-1.92, -0.44]	.002	-0.46	[-1.25, 0.33]	.253
2	-0.89	[-1.43, -0.35]	.001	-0.43	[-1.0, 0.15]	.146
3	-0.59	[-0.98, -0.21]	.003	-0.39	[-0.81, 0.03]	.066
4	-0.30	[-0.67, 0.07]	.111	-0.36	[-0.75, 0.04]	.077
5	-0.01	[-0.50, 0.49]	.980	-0.32	[-0.85, 0.21]	.231
6	0.29	[-0.40, 0.98]	.410	-0.29	[-1.02, 0.45]	.442
7	0.58	[-0.33, 1.49]	.208	-0.25	[-1.22, 0.72]	.608
Unsuccessful directives						
1	0.02	[-0.55, 0.60]	.932	0.30	[-0.31, 0.91]	.334
2	-0.16	[-0.56, 0.24]	.435	0.08	[-0.35, 0.50]	.723
3	-0.34	[-0.66, -0.03]	.034	-0.15	[-0.48, 0.19]	.388
4	-0.53	[-0.92, -0.14]	.008	-0.37	[-0.78, 0.04]	.078
5	-0.71	[-1.27, -0.15]	.014	-0.59	[-1.19, 0.00]	.050
6	-0.89	[-1.66, -0.12]	.023	-0.82	[-1.63, -0.00]	.049
7	-1.08	[-2.07, -0.09]	.033	-1.04	[-2.09, 0.01]	.051
Expansions						
1	0.69	[0.11, 1.27]	.020	1.07	[0.48, 1.66]	<.001
2	0.61	[0.15, 1.07]	.010	0.95	[0.48, 1.41]	<.001
3	0.53	[0.18, 0.89]	.003	0.82	[0.47, 1.18]	<.001
4	0.45	[0.19, 0.72]	.001	0.70	[0.43, 0.97]	<.001
5	0.38	[0.15, 0.60]	.001	0.58	[0.35, 0.81]	<.001
6	0.30	[0.04, 0.56]	.026	0.46	[0.19, 0.722]	.001
7	0.22	[-0.13, 0.56]	.211	0.34	[-0.01, 0.68]	.058
Unsuccessful directives controlling for expansions						
1	-0.11	[-0.70, 0.47]	.702	0.04	[-0.56, 0.64]	.883
2	-0.23	[-0.62, 0.17]	.265	-0.04	[-0.45, 0.36]	.839
3	-0.34	[-0.65, -0.02]	.035	-0.13	[-0.45, 0.19]	.430
4	-0.45	[-0.85, -0.04]	.030	-0.22	[-0.63, 0.20]	.307
5	-0.56	[-1.16, 0.04]	.066	-0.30	[-0.91, 0.31]	.331
6	-0.67	[-1.49, 0.15]	.108	-0.39	[-1.23, 0.45]	.363
7	-0.78	[-1.84, 0.27]	.146	-0.48	[-1.56, 0.61]	.387

[a] FC= Fluency and Connectedness Level; [b] ES=Estimated effect size for the association between maternal behaviour and concurrent language at each level of fluency and connectedness; [c] CI=Confidence Interval; [d] Language assessed using PLS-4

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